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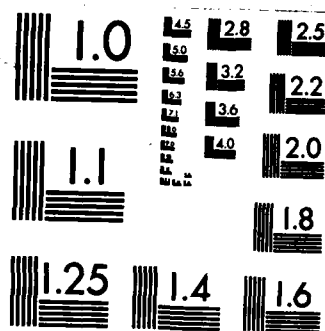
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CONTINUED DEVELOPMENT OF A DATA BASE  
MANAGEMENT SYSTEM PERFORMANCE MONITOR  
VOLUME I

THESIS

Timothy D. Bruner  
Captain, USAF

AFIT/GCS/ENG/84D-6

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CONTINUED DEVELOPMENT OF A DATA BASE  
MANAGEMENT SYSTEM PERFORMANCE MONITOR

VOLUME I

THESIS

Presented to the Faculty of the School of Engineering  
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Computer Engineering

Timothy D. Bruner, B.S.

Captain, USAF

December 1984

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## Preface

The purpose of this study was to continue the development of a performance monitor for a Data Base Management System. This report presents the System Analysis, Requirements, System Design, and Implementation of a Data Base Management System Performance Monitor. The emphasis of this study is on the presentation of performance data to the user. The Decision Support System was discussed as a flexible, user-friendly method for analyzing performance data.

I want to thank several individuals who provided valuable assistance to me during this thesis effort. First, I would like to thank my thesis advisor, Dr. Gary Lamont for his help and guidance. Additionally I would like to thank my thesis reader, Dr. Tom Hartrum. Finally, I want to thank my loving wife, Frances, and my sons, Jeremy and Steve, for their patience and support.

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Abstract

→ This <sup>thesis</sup> ~~investigation~~ focuses on the problem of analyzing the performance data collected on a Data Base Management System (DBMS). The performance data parameters are categorized and presented to the user using a Data Support System (DSS).

The generalized design for a DBMS performance monitor was used to design a user-friendly interface to DBMS performance data. The user interface to the DBMS performance monitor uses menus to allow the user to select DBMS performance parameter values. The DBMS performance parameter values can also be printed in the form of a performance report.

The design was implemented on a VAX 11/780 computer system using the VMS operating system. The TOTAL DBMS was used to collect performance data. The performance values were collected using existing software monitors, job accounting, system error log, and a utility developed at AFIT to collect Data Manipulation Language (DML) response performance data.

*Added a keyword: computer performance  
of the computer program (system error log,  
job accounting). ←*

## I. Introduction

### Background

The Data Base Management System (DBMS) is the software responsible for managing data contained in a computer data base. The performance of DBMSs is of interest to a wide variety of computer users. The Data Base Administrator (DBA) is responsible for the maintenance and performance of the data base. The users of the data base, both application and end users, are interested in the performance of their use of the DBMS. The overhead the DBMS places on the resources of the computer system must be measured and analyzed to improve the quality of computer performance.

The Data Base Performance Monitor provides a means of collecting and analyzing data base performance information. The thesis "Development of a Data Base Management System Performance Monitor" analyzed and designed a data base performance monitor which collected and displayed performance information (1). This Data Base Performance Monitor was implemented on the VAX 11/780 at AFIT using the TOTAL DBMS for the collection of data and contained four functional areas as shown in Figure I-1 and defined as:

1. User Interface - This section allows the user to specify the performance parameters, start and stop times, types of analysis, and method of presentation.

2. Measurement System and DBMS - This section initiates the monitor and records performance parameters.

3. Analyze Measurement Data Files - This section performs mathematical and statistical analysis on performance data.

4. Present Performance Measurement Data to User - This section displays the performance information to the user.

1. Lists
2. Tables
3. Graphs
4. Charts
5. Plots

Operations. The decision-making operations that can be performed on the information allows the DSS user to manipulate data for specific requirements. Example operations for a DSS are as follows:

1. Generate lists
2. Define tables
3. Draw graphs
4. Draw charts
5. Display plots

Memory Aids. Memory aids provide the DSS user the means of saving and recalling information. The memory aids needed for a SDSS are as follows:

1. Variable memory space
2. File storage of data
3. Data base information storage
4. Model information storage

The model base used in the DSS needs to support all levels of management decision making (10:149-171):

1. Operational
2. Tactical
3. Strategic
4. Mission

The capabilities of the MBMS include (10:33):

1. ability to create new models
2. ability to use existing models
3. ability to maintain a variety of models
4. ability to manage a library of model building blocks

#### Systems Analysis for DSS

The analysis of the requirements for a DSS uses an approach based on the requirements for the three major components of a DSS. The ROMC method of analysis uses four user-oriented processes: Representations, Operations, Memory Aids, and Control Mechanisms (10:96-118). This process-independent method allows the flexibility in design needed for an effective DSS.

Representations. The method of representing the data to the decision maker is important to the conceptualization of the information. A list of example representations for a SDSS follows:



Data Base Management Software (DBMS). The Data Base Management Software (DBMS) provides the ability to store and retrieve data and the relationships between data. The query language of the data base provides the means of accessing information stored in the Data Base (DB). The capabilities of the DBMS required for a DSS are (10:31-32):

1. Ability to use a variety of data sources
2. Ability to add and delete information
3. Ability to define data relationships
4. Ability to update information
5. Ability to manipulate information

In addition the DBMS must interface with the other components of the DSS.

Model Base Management Software (MBMS). The Model Base Management Software (MBMS) allows the decision maker to analyze information in the DSS. The types of models in the Model Base (MB) that are embedded in the DSS include the following:

1. Simulation
2. Statistics
3. Forecasting
4. Alternatives

DSS

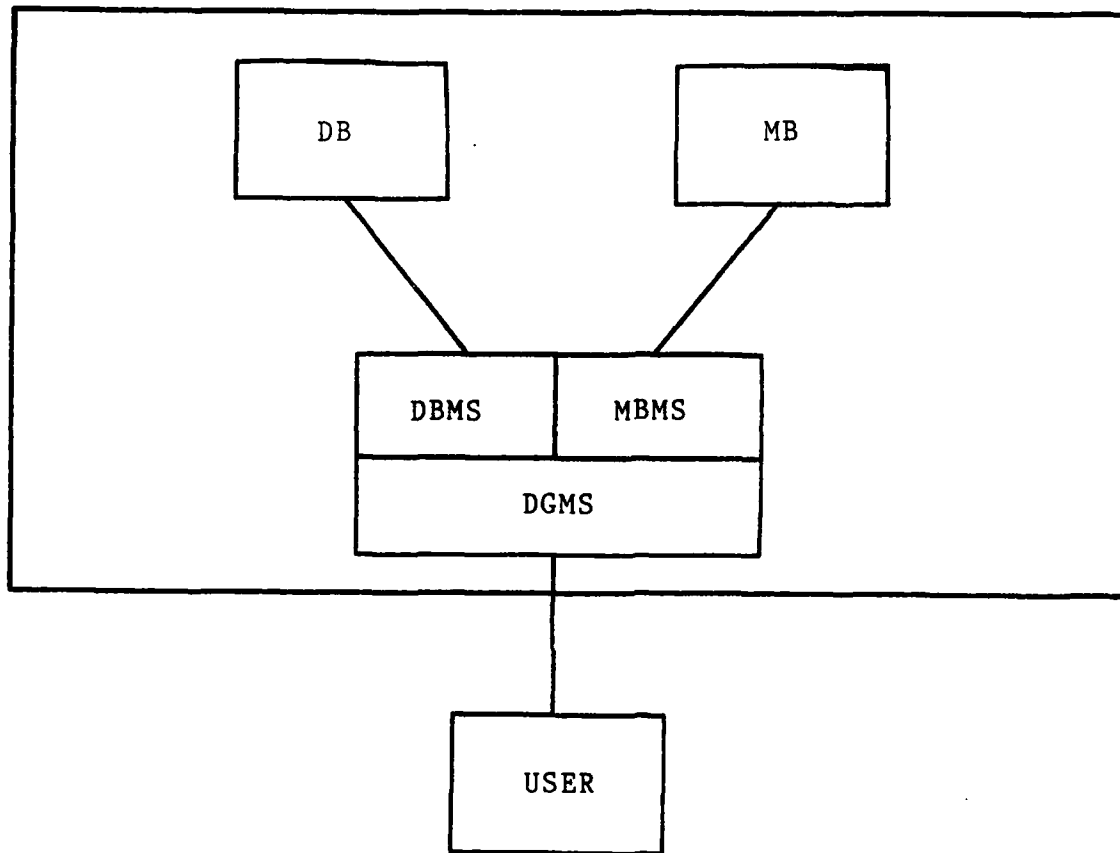


Figure II-1 Components of the Decision Support System  
Source (10: 28-35)

4. Input Form/Output Form Dialog - The input form/output form of dialog style uses a fill-in-the-blank format for the user.

5. Input-In-Context-Of-Output Dialog - The input-in-context-of-output dialog style presents an output form which the user can change parameters and see the results.

### Decision Support System

A Decision Support System (DSS) is a management decision system which is an interactive, user-friendly computer-based system that helps decision makers use data and models to solve unstructured problems (10:4). The Specific DSS (SDSS) is the hardware/software system that supports a specific decision application. The components of a DSS are shown in Figure II-1.

Dialog Generation and Management Software (DGMS). The DGMS is the interface between the user and the SDSS. This interface provides the power, flexibility, and usability needed to make the SDSS effective. Five types of dialog styles are discussed in the following sections (10:198-206).

1. Question-Answer Dialog - The question-answer dialog asks questions leading the user to the information needed for the decision.
2. Command Language Dialog - The command language dialog uses a language of verb-noun combinations for controlling the DSS.
3. Menu Dialog - The menu dialog allows the user to select from a menu of alternatives.

The DBA needs a flexible interface to data base information to perform these functions. The interface must support unstructured requests of data for decision making. The framework of the Decision Support System meets these requirements.

#### Qualifications for a DBA

The DBA must have an understanding of the needs of the user and the capability to meet these needs. The position requires sufficient authority to deal with the needs of the organization. The DBA must have the technical competence needed to manage the data base system (14:596-598).

Documentation and Forms. The DBA establishes and enforces documentation standards and naming conventions. The data dictionary is created and maintained by the DBA.

User Representative. The DBA must know the requirements of the users, to ensure the data they require is available. The DBA uses the user requirements for planning and data base definition.

Data Base Systems. The DBA must know the capabilities of the DBMS and how to maintain it. The DBA must be familiar with the operating system and the computer hardware. The DBA is responsible for backup and recovery of the data base.

Performance Monitor. The DBA collects and analyzes data about the performance of the computer system. The DBA investigates and responds to user problems. The DBA evaluates the impact of changes to the data base system.

Content and Structure. The DBA decides what data is to be included in the data base and the relationships between data. The DBA defines the access and validation procedures for the data base. He determines the physical representation of the data in the computer system and the best access method to use in retrieving information.

## II. System Analysis and Requirements

### Introduction

This chapter analyzes the system and defines the requirements for the DBA interface to the Data Base Performance Monitor. First, the many functions of the DBA are analyzed. Then the system analysis for a Decision Support System is described that meets the requirements for the DBA interface to the monitor information. The functional requirements of the system are analyzed using the analysis for the Decision Support System.

This chapter contains the functions and qualifications of the Data Base Administer, a description of a Decision Support System, the systems analysis for a Decision Support System, and the functional requirements for a Decision Support System.

### Data Base Administrator

The Data Base Administrator (DBA) is the person or group responsible for the management of the data base (9:396). The DBA must make decisions affecting the organization and use of the information stored by the organization. The functions of the DBA include the following (5:374-376, 3:25-27):

the VAX 11/780. A statistical package having the capability to perform variance and regression analysis from an application program is needed to analyze performance monitor data.

### Sequence of Presentation

Chapter 2 contains the system analysis and functional requirements for the Data Base Management System Performance Monitor. The analysis for the user interface is in the form of a Decision Support System. The functional requirements are contained in Appendix A and the set of performance measures are contained in Appendix C. Chapter 3 contains the system design for a generalized Data Base Management System Performance Monitor. The system design documentation uses SADT diagrams and data dictionary. The system design documentation is contained in Appendix D. Chapter 4 contains the implementation and testing of the Data Base Management System Performance Monitor on the VAX 11/780 using the VMS operating system. The implementation documentation uses structure charts and data dictionary. The implementation documentation is contained in Appendix E. Appendix F contains the User Manual for DBMON. Chapter 5 contains the results, conclusions, and recommendations of this study.



2. Familiarization with the current system
  - a. VAX 11/780 computer system
  - b. VMS operating system
  - c. DBMS performance monitor
  - d. Statistical packages
3. System design
  - a. Formulate system interface requirements
  - b. Modify the DBMS Performance Monitor
  - c. Develop system design
  - d. Document design
4. System implementation
  - a. Code programs
  - b. Test and validate implementation
  - c. Document implementation
5. System analysis
  - a. Validate system
  - b. Analyze monitor data

#### Equipment and Software

The computer equipment necessary for the DBMS performance monitor is the VAX 11/780 computer system and its peripherals. This computer system is currently available in the AFIT/ENG laboratory. Disk space for the DBMS performance monitor and the target DBMS is needed for the completion of the project. The VAX VMS operating system, support utilities, and compilers are available on

operational for the collection of performance data and testing of the DBMS performance monitor.

### Standards

Software engineering methods and techniques will be used in the requirement, design, implementation, and testing phases of this project. The techniques of Data Flow Diagrams, Structured Analysis and Design Technique (SADT), and Structure Charts will be studied as possible documentation to the design process (7).

### Approach

The approach to solving the problem will be the following five steps:

1. Literature review of the following areas:
  - a. User-friendly interfaces
  - b. Types of DBMS performance monitor users
  - c. Requirements of DBMS performance monitor users
  - d. Analysis of monitor data
  - e. Analysis of the existing DBMS Performance

Monitor

### Purpose

The purpose of this study is to develop the DBA interface for a Data Base Management System Performance Monitor. The interface will meet the varying requirements of the different functions of the DBA. This will give the DBA the tools needed to evaluate and analyze DBMS performance.

### Scope

This project will consist of analyzing the environment of the DBMS performance monitor and determining the requirements for the DBA. Using these requirements, the performance data parameters will be analyzed and categorized for the DBMS performance monitor user. The user interface to the DBMS performance monitor will be implemented allowing selection of generalized or specific subsets of performance parameters and performance monitor reports.

### Assumptions

1. The original DBMS performance monitor (1) will be assumed to be correct unless reason is found to prove otherwise.
2. The VAX 11/780 computer system and the VMS computer operating system prove accurate performance data on computer system resource usage.
3. The TOTAL data base management system will be

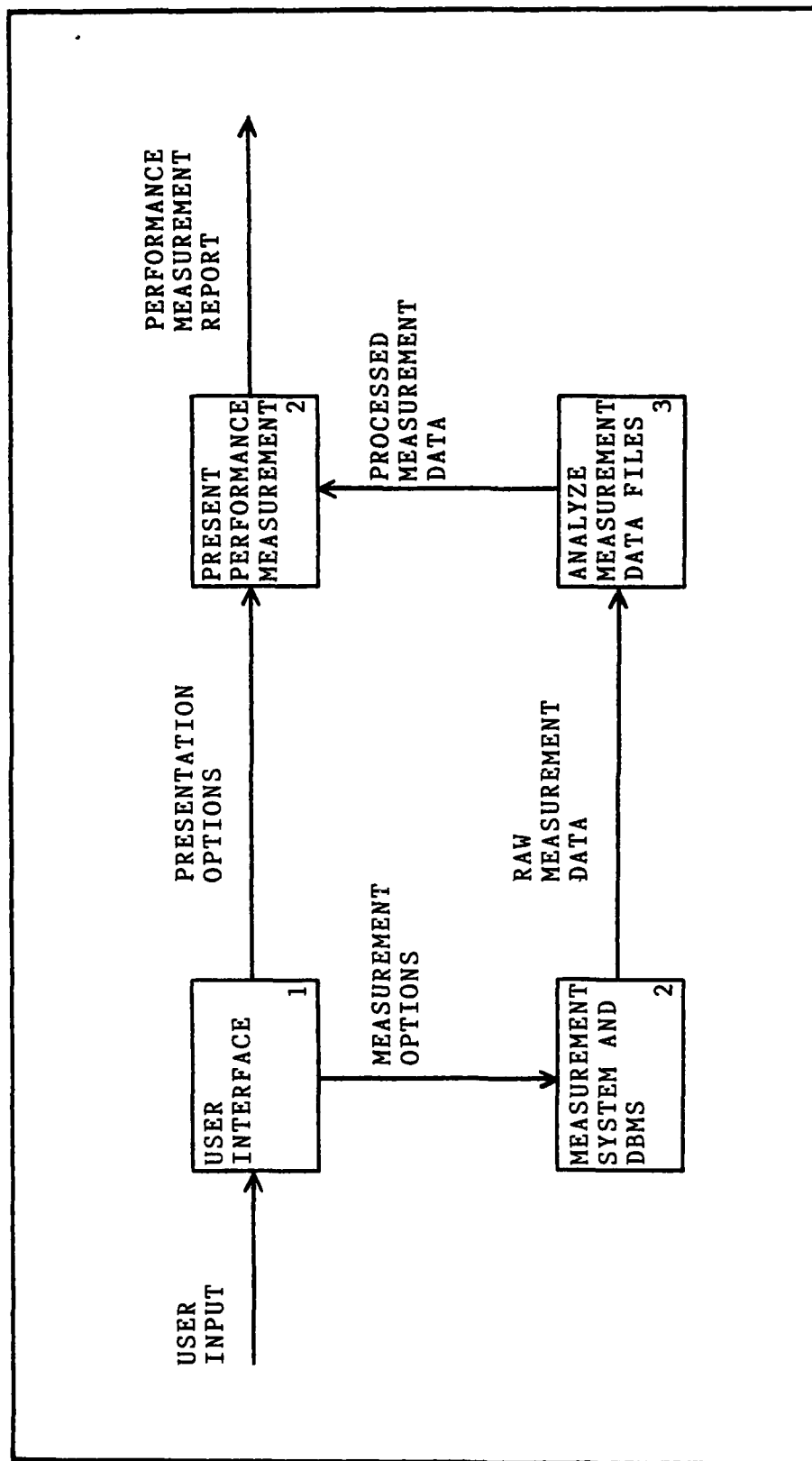


Figure I-1 - DBMS Performance Monitor Block Diagram.  
Source (1: Sec II,4-9)

Control Mechanisms. The control mechanisms provide a user-friendly interface to the DSS. A list of the characteristics of these control mechanisms follows:

1. Standard conventions of interaction
2. Help or Learn commands
3. Default values

Functional Requirements

The functional requirements for the DBA interface to the Data Base Performance Monitor were formulated using the approach described for the system analysis for a DSS. The following sections describe the general and specific requirements using ROMC system analysis.

Representations. The methods used to represent the performance data to the DBA must be in a form suitable for data base decision-making. The functional requirements for the DSS representations follow:

1. Lists - list performance data.
2. Graph - display information graphically to the user.
3. Tables - display information with headings and totals.
4. Plots - plot performance data.
5. Charts - make pie charts and histograms of data.

6. Reports - generate custom reports from performance data.

Operations. The operations which the DSS is capable of performing determine the flexibility of the decision-making capabilities. The following are the specific operations needed for the DBA SDSS:

1. Gather data on DBMS performance.
2. Select performance data for analysis.
3. Manipulate performance data.
4. Categorize and store performance data.
5. Generate statistics on performance data.
6. Generate and analyze decision alternatives.
7. Produce scattergram of performance data.
8. Produce histograms of data.
9. Plot line graphs of data.
10. Print reports on data base performance.

Memory Aids. Memory aids are used in the DSS to support the use of the representations and operations. The memory aids needed for the DBA interface to the performance data are:

1. Workspace for temporary storage of data variables.
2. File space for new performance data.
3. Data Base for the storage of performance data.

4. Data Base for storage of the model base.

Control Mechanisms. The control mechanisms for the DSS help the user to use the DSS. The control mechanisms for the DBA DSS follow:

1. Common style of presentation to the DBA using the menu dialog style.
2. Use of default values for DSS parameters.
3. Help screens for on-line assistance.

### Summary

This chapter presented the system analysis and requirements for the Data Base Performance Monitor. The functions and qualifications of the Data Base Administrator were discussed. The Decision Support Systems was described and the following components were analyzed:

1. Dialog Generation and Management Software
2. Data Base Management Software
3. Model Base Management Software

The systems analysis for a Decision Support System was based on the ROMC approach. The following is a list of the ROMC processes:

1. Representations
2. Operations
3. Memory Aids
4. Control Mechanisms

Finally the functional requirements for the DBA user interface to the Data Base Performance Monitor were formulated.



### III. Systems Design

#### Introduction

This chapter presents the system design for a generalized data base management system performance monitor. The functional requirements presented in chapter II were used as a basis for the system design process. The top-level design activities came directly from the four major functional requirement areas (Appendix A). These top-level activities were further refined until all functional requirements were satisfied.

This chapter contains the design documentation, the design descriptions, and the test plan for the DBMS performance monitor.

#### Design Documentation

The design documentation used for the DBMS performance monitor was Data Flow diagrams and the Structured Analysis and Design Technique (SADT) diagrams and their associated data dictionaries. The Data Flow diagrams were used to show general high-level flow of data in the DBMS performance monitor. SADT diagrams were used as the primary system design documentation. The complete system design package is contained in Appendix D.

### Data Flow Description

The general data flow for the DBMS performance monitor is shown in Figure III-1. The User Input to the DBMS performance monitor is translated by the User Interface into the set of commands needed by the system. The Measurement Control Commands control the measurement session. These commands control start/stop time and the set of performance parameters measured. The Analysis Commands control the analysis of the performance data by performing any mathematical analysis required by the user. The Presentation Commands control whether the performance measurement data is presented on a display terminal or printed on the system printer. The Measurement Data Files record performance data from the measurement tools. The Analyzed Measurement Data Files are merged and formatted for presentation to the user. The Performance Measurement Report outputs the performance data to the user in the form of terminal screens or printed pages.

### Design Descriptions

The system design presented in this chapter uses a special top-down system design technique (1). The system design was analyzed by treating the design as a Reader Kit (6). In the process of checking the design, the format of the design was changed to meet the development documentation standards of AFIT/ENG. The system design was analyzed using the Author/Reader Cycle technique with the following Reader

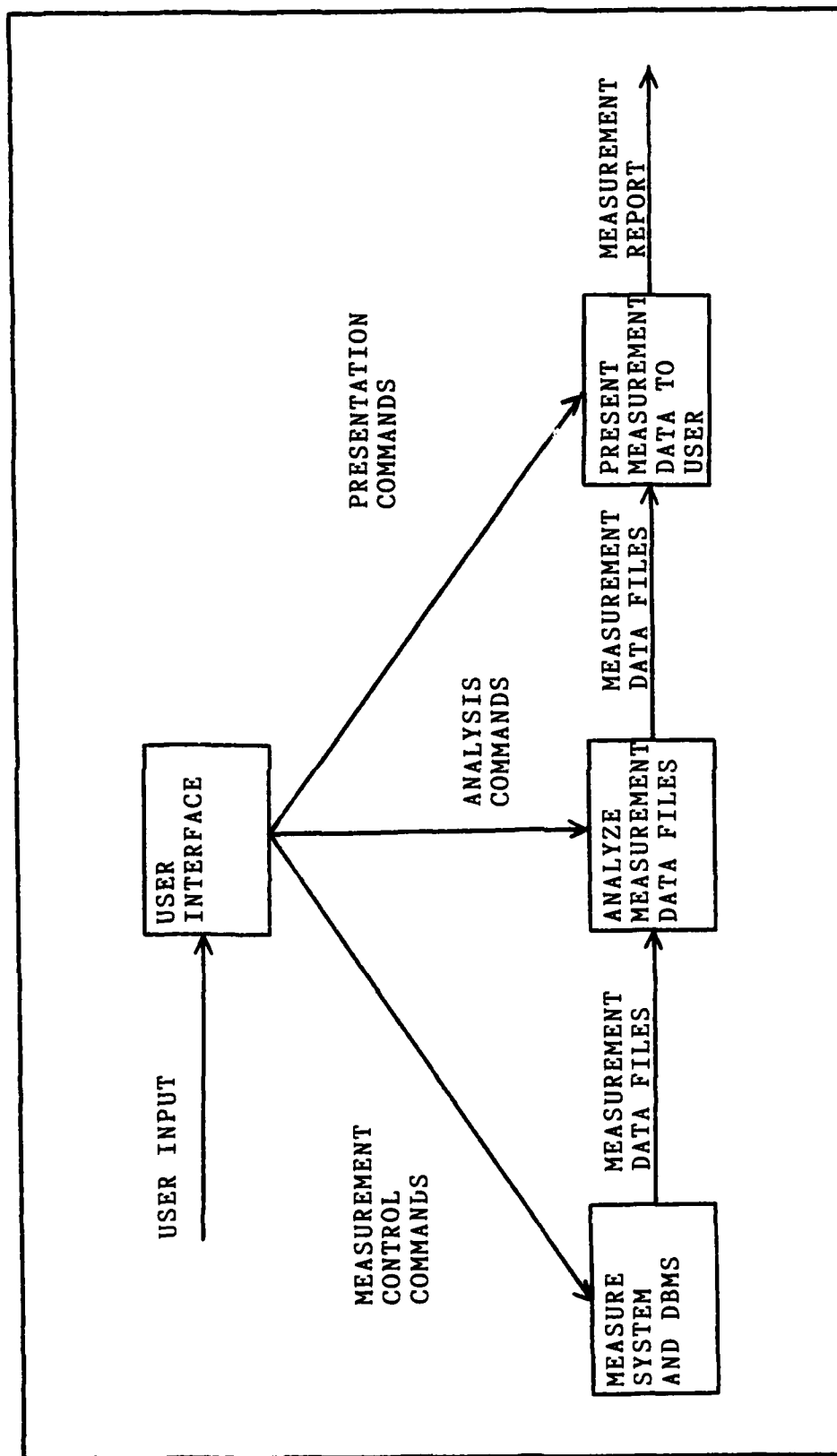


Figure III-1 - DBMS Performance Monitor.

responsibilities (6):

1. correct syntax
2. clarify terminology
3. check consistency
4. assure accuracy
5. check completeness

The top level SADT diagram for the performance monitor is shown in Figure III-2. The four major functional requirements (Appendix A) of the performance monitor were used to define the major design activities. The User Interface accepts input from the user and generates a set of presentation, analysis, and measurement control commands to satisfy the user's needs. The Measure System and DBMS activity initiates the data collection utilities and records performance data. The Analyze Measurement Data Files activity combines the data produced by the data collection utilities and produces formatted performance data files. The Present Performance Measurement Data to User activity displays and/or prints the performance data in the form of a report to the user.

The following is a description of the major activities in the system design of the performance monitor:

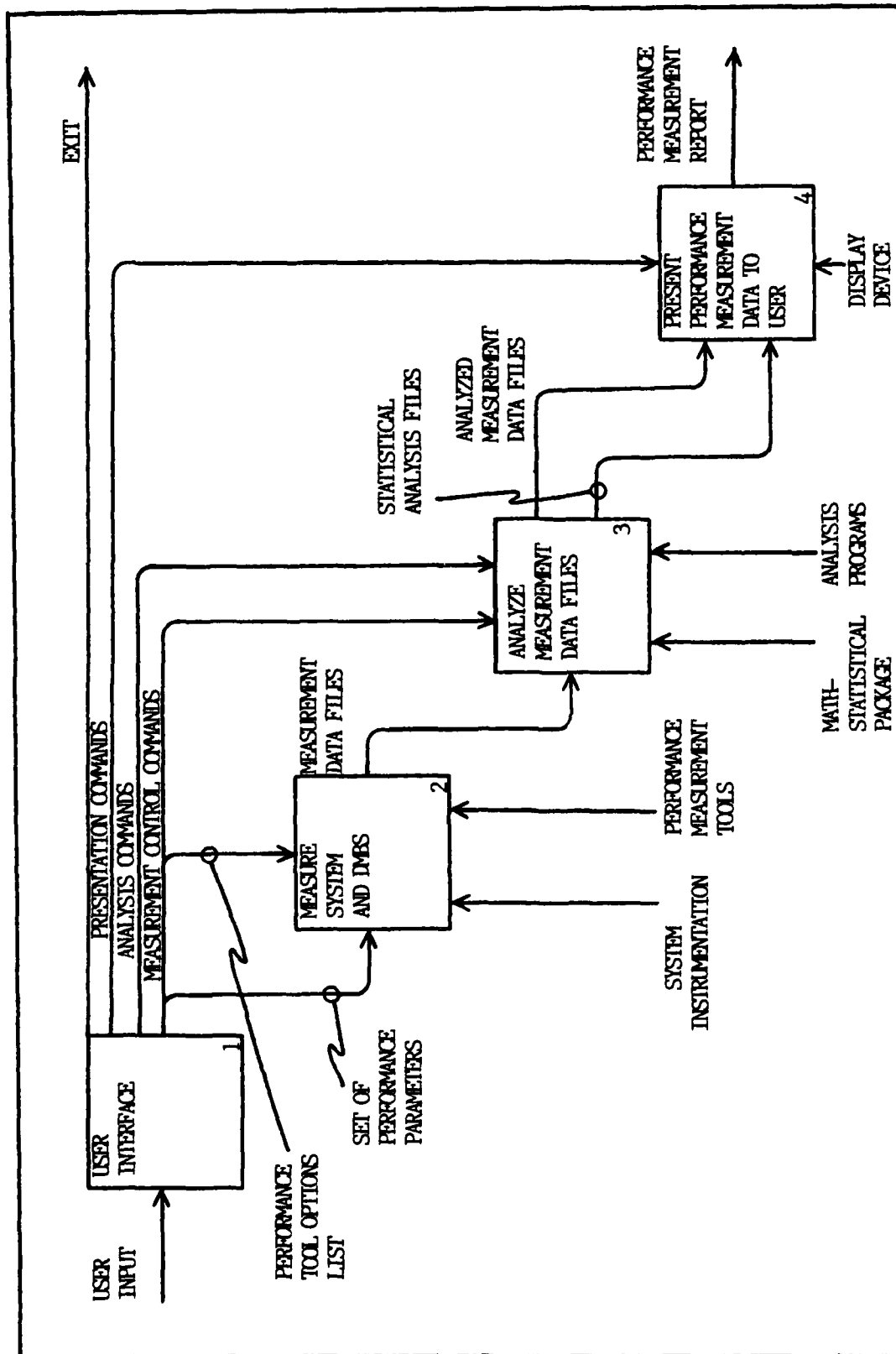


Figure III-2 DBMS PERFORMANCE MONITOR SADT

User Interface. The User Interface is used to control the operation of the performance monitor (See Figure III-3). It accepts input from the user, builds commands, and displays terminal screens. User input to the User Interface is evaluated for acceptable input and used to build commands, options, and performance parameters. The User Interface activity builds the set of performance parameters needed to analyze performance measurement data, the list of performance tools needed to collect the raw performance data, the analysis commands for the formatting of the raw performance data, and the presentation commands to display the analyzed performance data to the user. The Display Screen Format activity generates user-friendly screen formats and error messages for data input, menu displays, data analysis, and data presentation terminal screens. The User Interface activity satisfies the following functional requirements: 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, and 1.6 (Appendix A).

Measure System and DBMS. The Measure System and DBMS activity initiates performance measurement and system instrument tools which collect and record measurement data for a selected set of performance parameters (See Figure III-4). The measurement control commands generated by the User Interface specify and control a performance measurement session. The Map Performance Parameters to Measurement Source activity maps the set of performance parameters

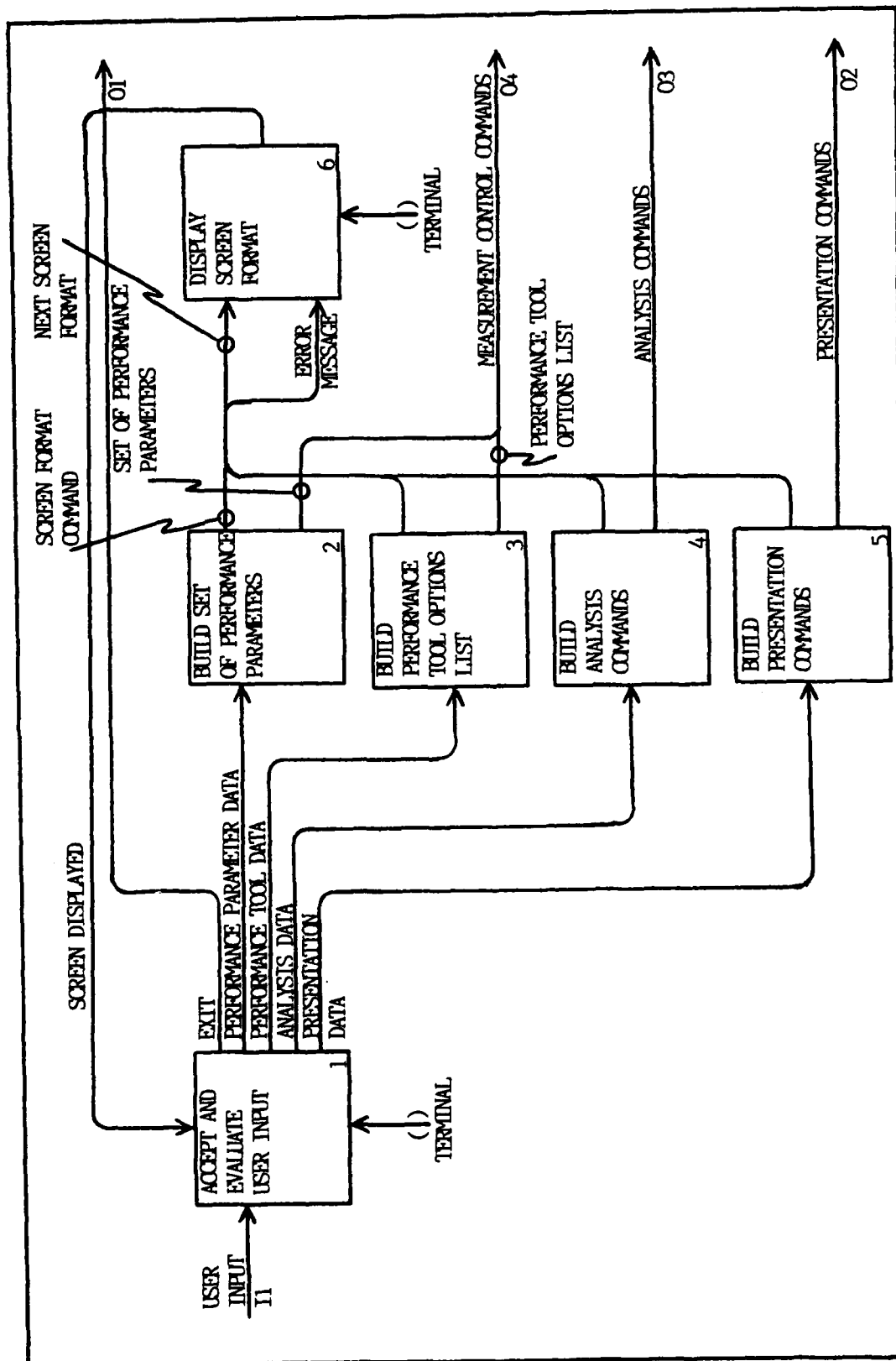


Figure III-3 USER INTERFACE SADT

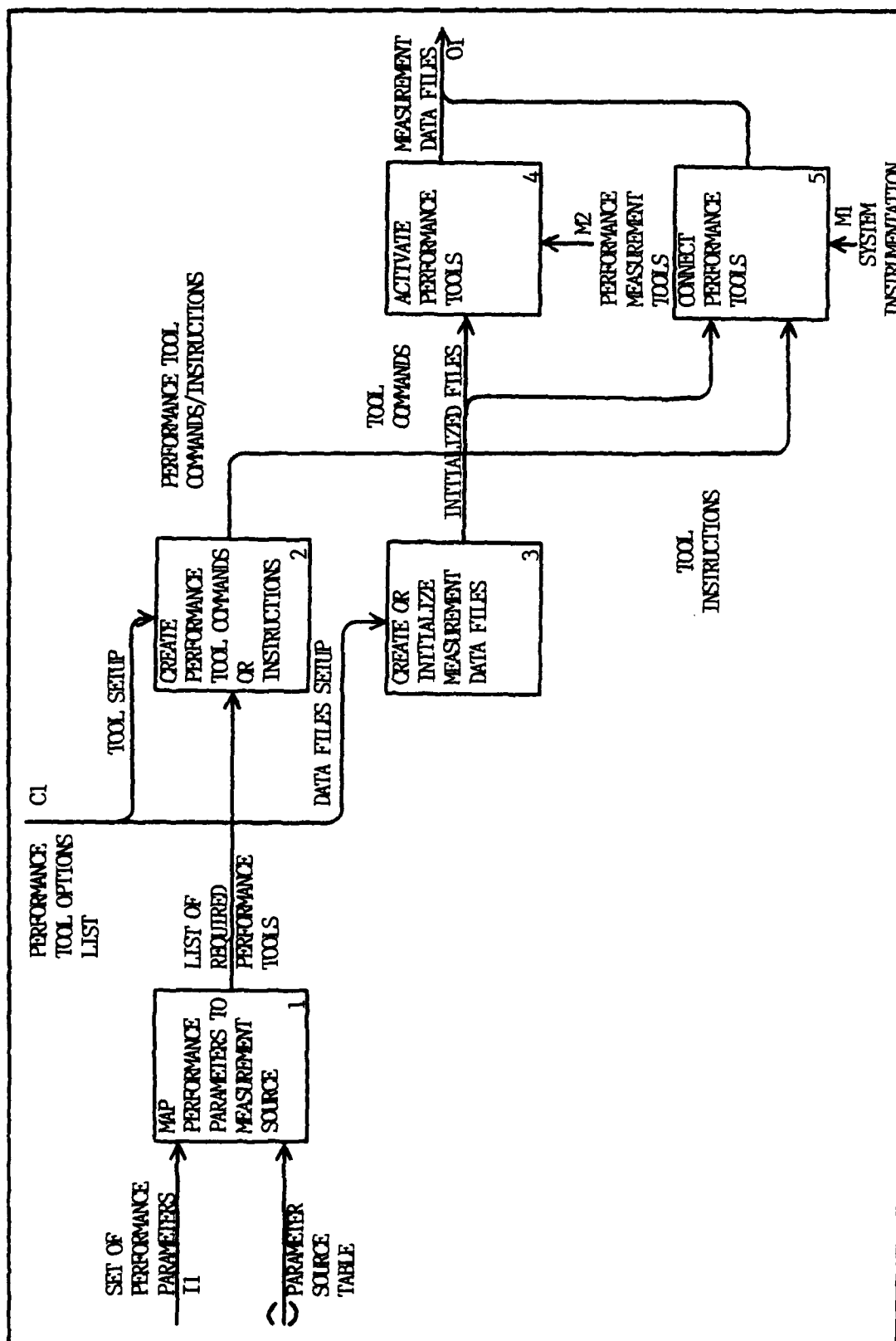


Figure III-4 MEASURE SYSTEM AND DBMS SADT



selected by the user to a list of performance tools required to collect the performance data. The Create Performance Tool Commands or Instructions activity creates a list of performance tool commands and instructions used to activate the performance tools. The Create/Initialize Measurement Data Files activity creates new data files or initializes existing data files used to record raw performance measurement data. The Activate Performance Tools activity uses the tool commands to activate and record performance measurement data. The Connect Performance Tools activity uses the tool instructions to describe the connection of performance tools requiring human intervention. The Measure System and DBMS activity satisfies the following functional requirements: 2.0, 2.1, 2.2, 2.3, and 2.5 (Appendix A).

Analyze Measurement Data Files. The Analyze Measurement Data Files activity merges the measurement data files produced by the performance tools into an analyzed measurement data file and formats the data for presentation to the user (See Figure III-5). This activity also calculates values for performance parameters not directly measurable by the performance tools. The data analysis of the measurement data is controlled by the measurement control and analysis commands input by the user and performed by the analysis programs and math-statistical packages. The Analyze Measurement Data Files activity executes the analysis programs and math-statistical packages

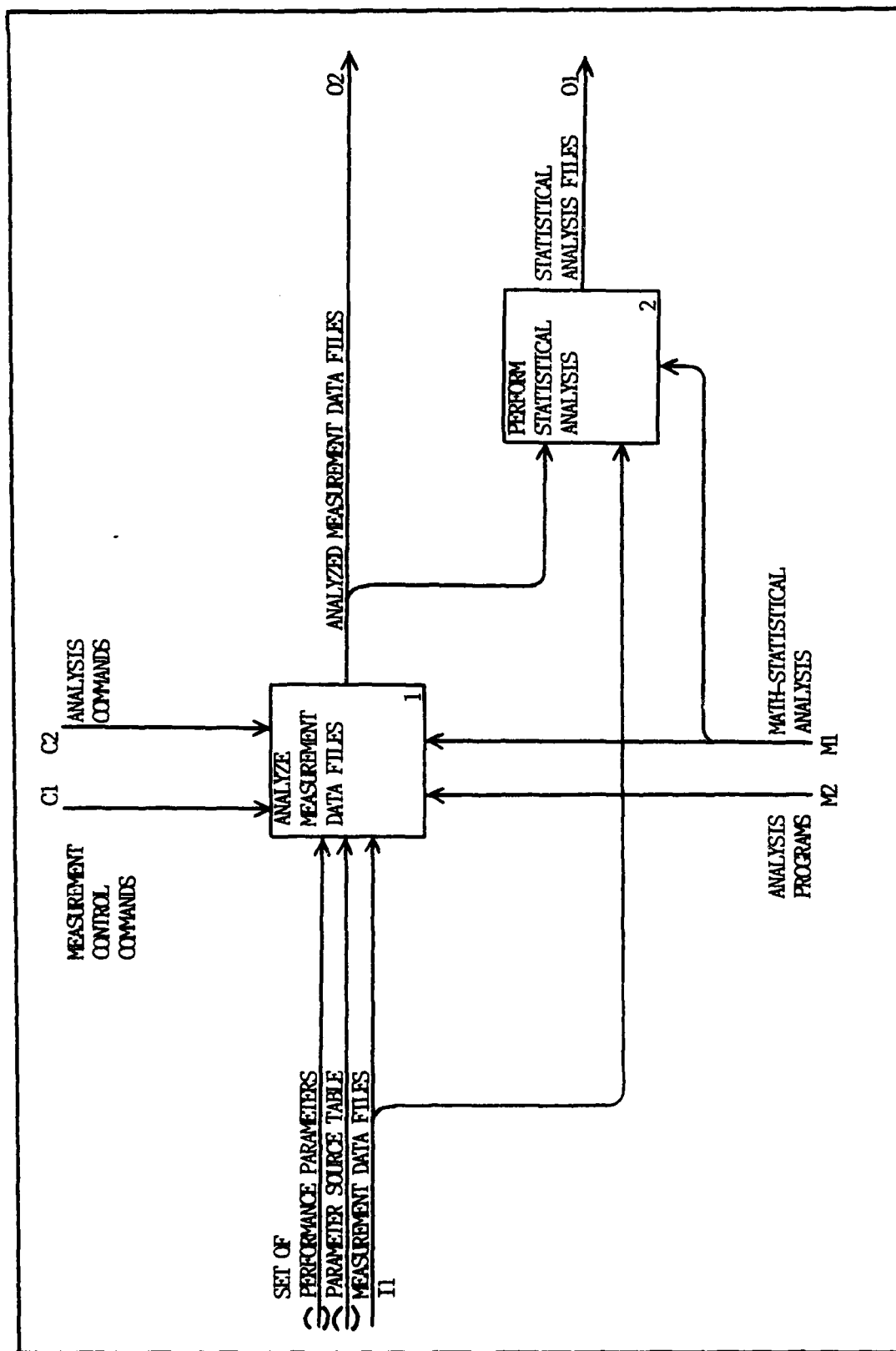


Figure III-5 ANALYZE MEASUREMENT DATA FILES SADT

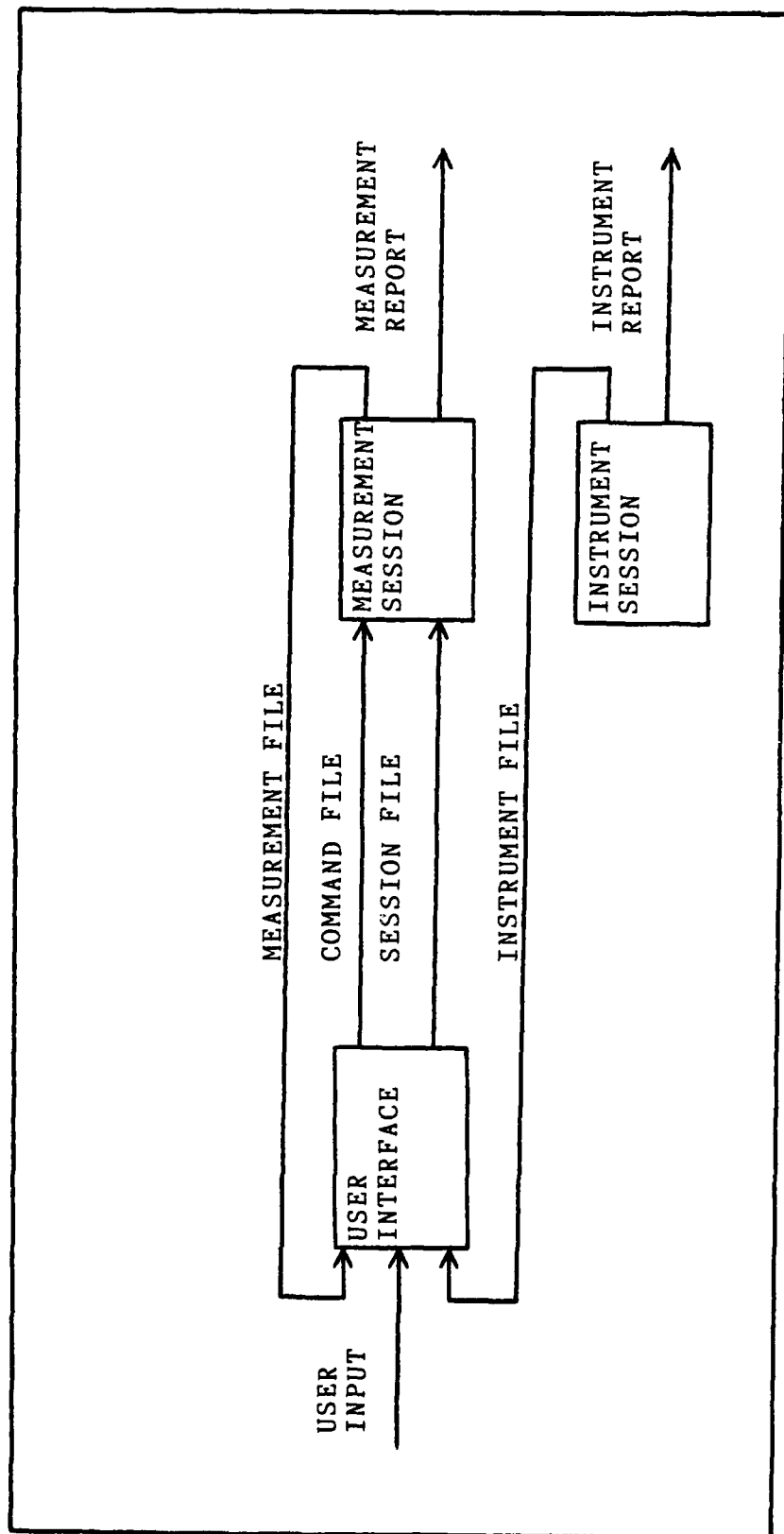


Figure IV-1 - DBMON Block Diagram.

### Programming Language Selection

The programming language selected for the implementation of the DBMS performance monitor was VAX Pascal (12). The user interface program and the instrument utility data analysis program developed for DBMON are written in Pascal (1:V,4-6). The instrument utility modules are coded in VAX MACRO-11 (1:V,13-14). The Pascal programming language is the primary development language used at AFIT on the VAX/VMS system.

### Software Implementation

The DBMON software was implemented using the program design contained in Appendix E. Figure IV-1 contains a block diagram of the three sections and data flow of the DBMON implementation. The User Interface inputs the user commands and generates a command file used to control the measurement session. The session file contains measurement session information, such as: session name, start/stop times, and session status. The Measurement Session uses the command file to gather performance measurement data and generate the performance measurement report and the measurement data file. The Instrument Session uses the instrument utilities to collect instrument data and generates the instrument performance report and the instrument data file. The measurement data file and instrument data file are then available to be displayed to the user by the User Interface. The following is a

TABLE IV-2

EFFECTIVENESS MEASURES

Performance Index	Performance Parameter	Source	Option
PRODUCTIVITY	System throughput	Account Utility	/SUMMARY
	DBMS throughput by DML statement	Instrument Program	
	Retrieval	Instrument Program	
	Storage	Instrument Program	
	Control	Instrument Program	
RESPONSIVENESS	Special purpose	Instrument Program	/SUMMARY
	System turnaround	Account Utility	
	DBMS turnaround	Account Utility	
	System response time	Instrument Program	
	DBMS response time	Instrument Program	
INTEGRITY	Availability	SYE Utility	/SUMMARY

TABLE IV-1

EFFECTIVENESS MEASURES

Performance Index	Performance Parameter	Description
PRODUCTIVITY	System throughput	Number of jobs executed per unit of time
	DBMS throughput by DML statement	Number of DML statements executed per unit of time
	Retrieval	Number of DML retrieval statements
	Storage	Number of DML storage statements
	Control	Number of DML control statements
RESPONSIVENESS	Special purpose	Number of DML special purpose statements
	System turnaround	Elapsed time between submitting a job or command and receiving the output
	DBMS turnaround	Elapsed time between submitting a DBMS task and receiving the output
	System response time	Elapsed time of user requests and transactions in an interactive of real time mode
	DBMS response time	Elapsed time of a DML statement in an interactive mode
INTEGRITY	Availability	Percentage of time the computer system and DBMS is available to users

Instrument Utility. The instrument utility is a collection of modules written by Capt Bailor to collect DBMS performance data (1: V,13-18). These modules are imbedded into the TOTAL application program to collect data at the Data Manipulation Language (DML) level of the DBMS. The instrument utility produces raw performance data that is reduced in the analysis programs of the DBMS performance monitor.

#### Measurable Performance Parameters

The set of measurable performance parameters were developed from the original systems analysis (1: II). The performance parameters were classified into efficiency measures and effectiveness measures. Each class of performance measure was further divided into the parameter index and the performance parameter. Appendix C contains a complete table of the measurable performance parameters. This table contains a list of performance parameters by measure and performance index. The table contains a description of each performance parameter and the source for collecting data on the parameter. Table IV-1 shows a sample from the DBMON performance measure table with the performance parameter descriptions. Table IV-2 shows the same performance parameters with the parameter source.

## Performance Measurement Tools

The performance measurement tools used on the VAX 11/780 to collect performance data were: VAX Monitor Utility, VAX Accounting Utility, VAX SYE Utility, and the Instrument Utility. The following is a general description of each of these performance measurement tools.

VAX Monitor Utility. The VAX Monitor Utility is a software monitor used to collect data on the computer system performance (13:Chapter 12). The monitor collects data in time intervals. Performance data from the monitor is used by DBMON from four classes of data: IO, Modes, States, and FCP. The data produced by the monitor utility is in the form of an ASCII print file report.

VAX Accounting Utility. The VAX Accounting Utility uses the VAX job accounting file to produce performance data (13:Chapter 1). The accounting utility reads the job accounting file and produces a summary report for the selected jobs. The summary report is in the form of an ASCII print file.

VAX SYE Utility. The VAX SYE Utility uses the system error log file to generate performance values for system error rates (13:Chapter 17). The SYE utility produces summary reports from the error log file. The summary report is in the form of a print file with special control characters.



9. Continue the development of the Specific Decision Support System (SDSS) for the User Interface program of DBMON.

A priority was assigned to each section of the implementation effort. The following is a list of the priorities for each section starting with the highest:

1. Implement the data analysis programs.
2. Implement the performance measurement report.
3. Implement sections of the user interface (1).
4. Implement the SDSS sections of the user interface.

#### Test Procedures

The test plan presented in chapter III was implemented using incremental testing based on software engineering. The test procedure used unit, integration, validation, and system testing (8: 295-305). Unit testing ensures each module performs correctly. Integration testing ensures modules of a program communicate correctly with each other. Validation testing ensures the program meets the functional requirements. System testing ensures all software in the system performs correctly and meets the functional requirements.

The operating system used on the VAX 11/780 is version 3.6 of the VAX/VMS operating system (11). Programming languages available on the system are: MACRO-11 assembly, FORTRAN, C, and Pascal. The Data Base Management system currently used on the VAX is TOTAL version 2.1 marketed by CINCOM Systems, Inc (2). Reference (1:IV,6-15) contains a description of the TOTAL DBMS running under VAX/VMS.

#### Implementation Plan

The steps followed in the implementation of the DBMS performance monitor included:

1. Understand the VAX 11/780 hardware configuration.
2. Understand the VAX/VMS operating system and commands.
3. Study the performance measurement tools available on the VAX.
4. Understand the operation and use of the TOTAL DBMS.
5. Install the DBMS performance monitor (DBMON).
6. Operate and test the DBMON programs already developed.
7. Develop the Performance Measurement Report for the DBMS performance monitor.
8. Develop the analysis programs for the performance measurement data.

## IV. Implementation and Testing

### Introduction

This chapter presents the implementation and testing of the DBMS performance monitor on a Digital Equipment Corporation (DEC) VAX 11/780 computer running the TOTAL DBMS. This chapter includes the VAX 11/780 configuration, the implementation plan, test procedures, programming language selection, software implementation, and the operation of DBMON. The software implementation section contains the software description, data structures, program implementation, and testing. Appendix E contains the detailed structure charts and data dictionary for the software developed in this thesis investigation.

### VAX 11/780 Configuration

The DBMS performance monitor was implemented on the VAX 11/780 located in the AFIT/ENG Laboratory. The computer system is primarily used as a research system. A description of the hardware configuration is contained in Appendix B.

### Summary

This chapter presented the top-level system design for the DBMS performance monitor. The chapter contained the design documentation, data flow description, design description, and test plan. The design documentation used was the Data Flow diagram and the SADT diagram (Appendix D). The data flow description presented the general flow of data required for the DBMS performance monitor. The design description presented the design of the major activities of the DBMS performance monitor. The test plan for the DBMS performance monitor was described and a sample test module was discussed.

REQUIREMENT: 1.3 - Allow the user to inspect the status  
of the measurement collection process.

TEST CASE(S):

1. No collection processes have been entered.
2. No active collection processes.
3. Both active and inactive collection processes.

EXPECTED RESPONSE:

1. No status is reported.
2. Show the hibernating processes.
3. Show status of the active processes and all  
the hibernating processes.

RESULTS:

CASE 1. - PASS:\_\_\_\_\_ FAIL:\_\_\_\_\_ DATE:\_\_\_\_\_

CASE 2. - PASS:\_\_\_\_\_ FAIL:\_\_\_\_\_ DATE:\_\_\_\_\_

CASE 3. - PASS:\_\_\_\_\_ FAIL:\_\_\_\_\_ DATE:\_\_\_\_\_

TESTED BY:\_\_\_\_\_

REMARKS:

Figure III-7. Sample Test Plan.

Measurement Data to User activity satisfies the following functional requirements: 4.0, 4.1, 4.2, and 4.3 (Appendix A).

#### Test Plan

A formal test plan to test the validity of the system design for the DBMS performance monitor has been developed (1). A set specific of tests for the generalized design was developed using the functional requirements (Appendix A). A sample test module is shown in Figure III-7. The test plan contains the functional requirement, specific test cases, expected results of the test cases, actual results of each test case, and a remark section. The complete test plan for the DBMS performance monitor system design can be found in Appendix D (1). No changes were made in the test plan as a result of the system design of the DBMS Performance Monitor.

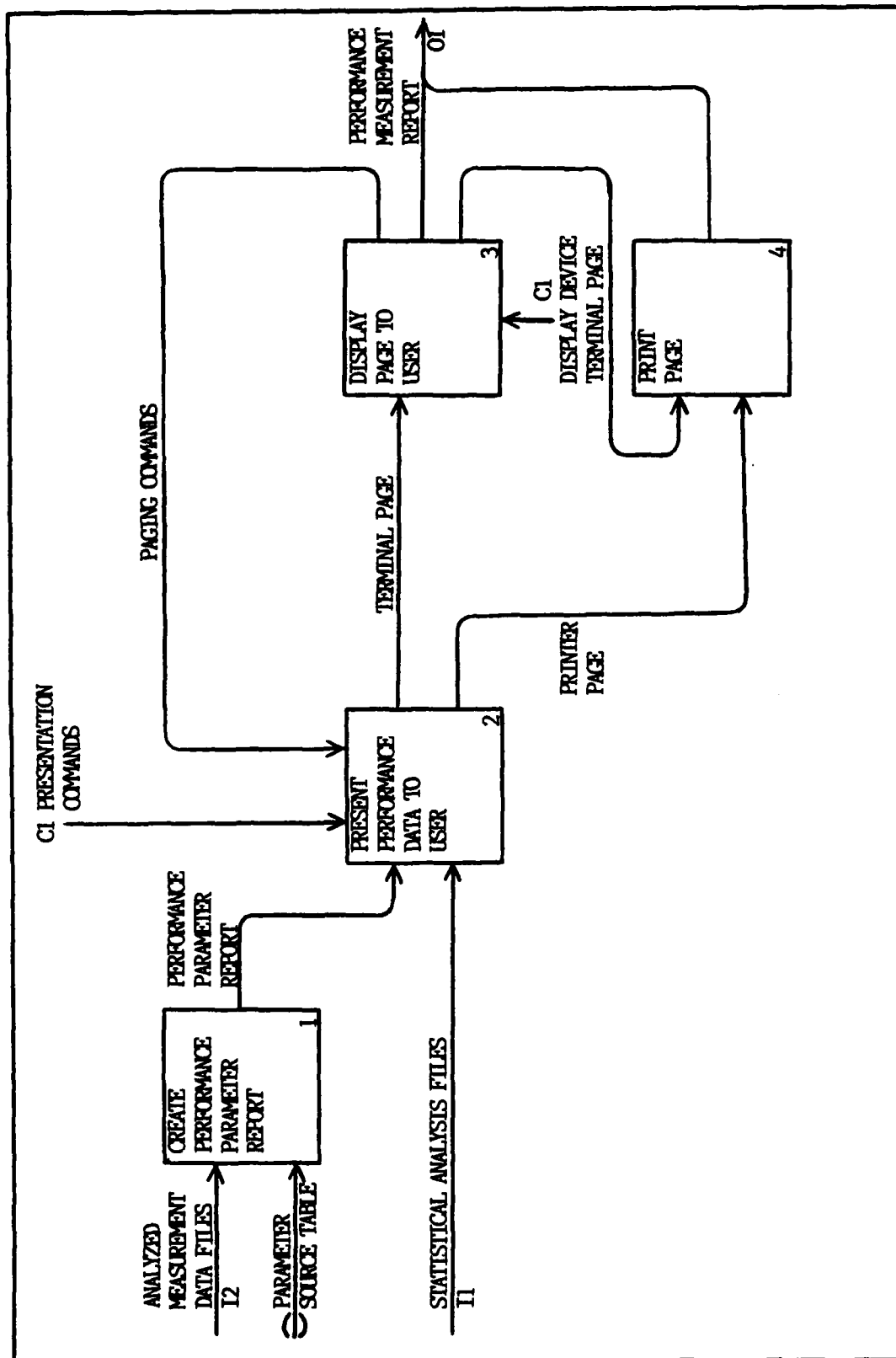


Figure III-6 PRESENT PERFORMANCE MEASUREMENT DATA TO USER SADT

to calculate values for performance parameters that are not directly measurable by the performance tools. The Perform Statistical Analysis activity uses the math-statistical package to perform requested statistical analysis on the performance measurement data. The Analyze Measurement Data Files activity satisfies the following functional requirements: 3.0, 3.1, 3.1.1, and 3.2 (Appendix A).

Present Performance Measurement Data to User. The Present Performance Measurement Data to User activity displays the analyzed measurement data to the user in the form of a performance measurement report (See Figure III-6). The performance measurement report can be displayed on a terminal screen or printed on the system printer. This activity displays the data in the analyzed measurement data file and the statistical analysis files controlled by the presentation commands. The Create Performance Parameter Report activity creates the performance parameter report from the analyzed measurement data files organized by parameter index and parameter name. The Present Performance Data to User activity uses the presentation commands to display the performance parameter report to the user. The Display Page to User activity displays a screen of the performance parameter report to the user. It allows the user to select a desired section of the report. The Print Page activity prints a page of the performance parameter report on the system printer. The Present Performance



description of each section of DBMON.

User Interface. The User Interface allows the user to select measurement session options and analyze performance data. The User Interface is user-friendly and menu driven. It controls the operation of the DBMS performance monitor.

Data Structures. The User Interface uses two files to control the operation of DBMON; Session File and Command File. The session file is used to save the measurement session options input by the user and to communicate the status of the measurement session to the user. Table IV-3 shows the contents of the session file record.

TABLE IV-3  
Session File Information

Field	Description
NAME	Session Name
STARTDATE	Start Date
STARTTIME	Start Time
STOPDATE	Stop Date
STOPTIME	Stop Time
ANALYSIS	Type of Data Analysis
PRESENTATION	Method of Data Presentation
INTERVAL	Collection Interval for the Monitor
STATUS	Current Status of the Session
PARAMETERSET	Set of Measurement Parameters

The command file contains the commands needed to initialize the measurement data files, activate the measurement performance tools, generate the measurement file, and print the measurement performance report. An example of the command file is shown in the following section.

Program Implementation. The block diagram for the User Interface is shown in Figure IV-2. This diagram contains the top-level menu for DBMON. The Main menu allows the user to select the following menus: Establish Measurement Session, Show Session Status, Delete Measurement Session, Analyze Data, and Exit Program. The Establish Measurement Session menu allows the user to select measurement session options, analysis options, and presentation options. The session file and command file are generated using the options selected by the user. This section of DBMON was implemented in Capt Bailor's thesis (1).

The Show Status selection displays the measurement session information and the current status of the measurement session. The Delete Measurement Session selection displays the session information of the current measurement session and prompts the user for deletion of the session. The Analyze Data menu is the SDSS portion of the DBMS performance monitor. Figure IV-3 shows the block diagram of the Analyze Data menu selections. The

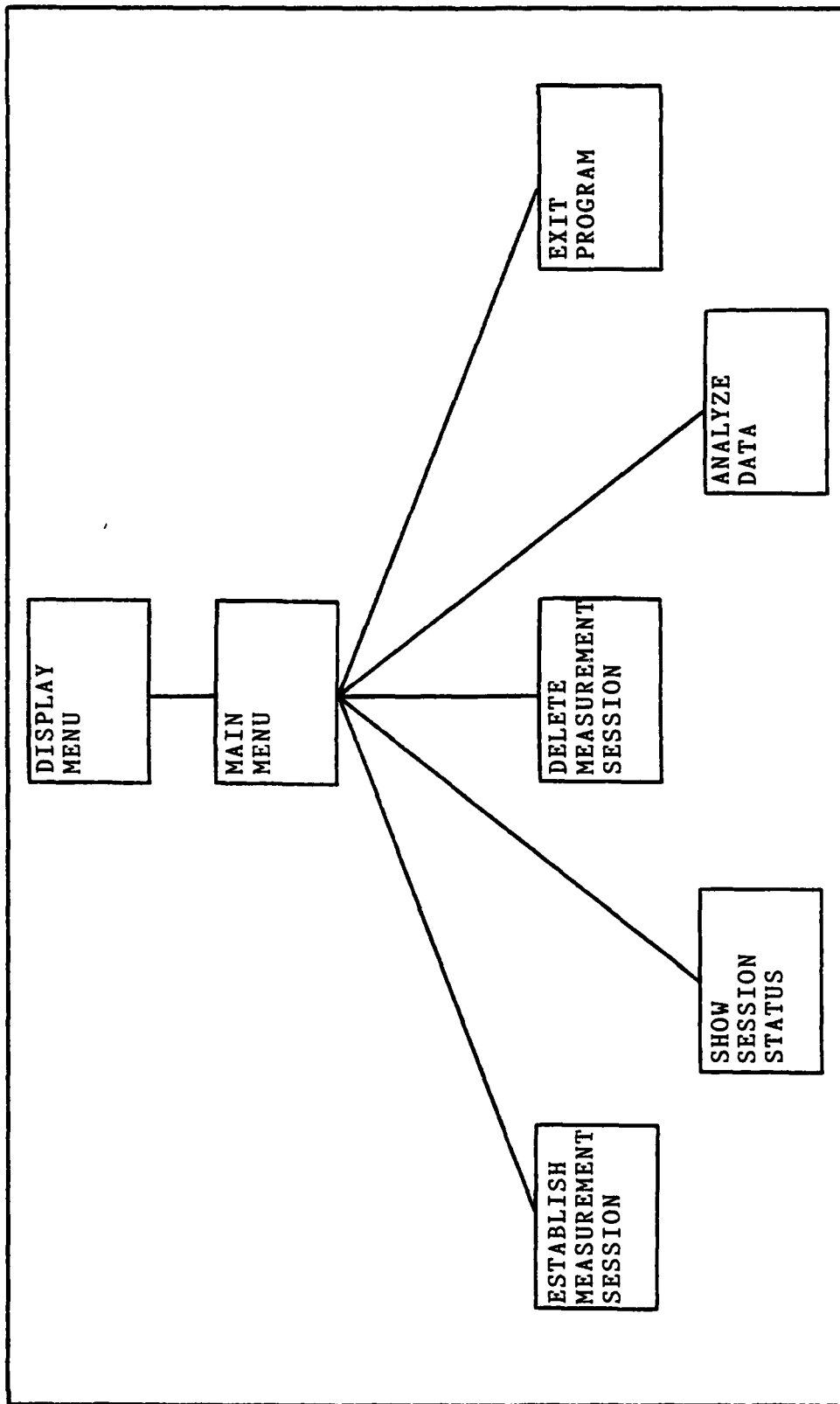


Figure IV-2 - User Interface Block Diagram.

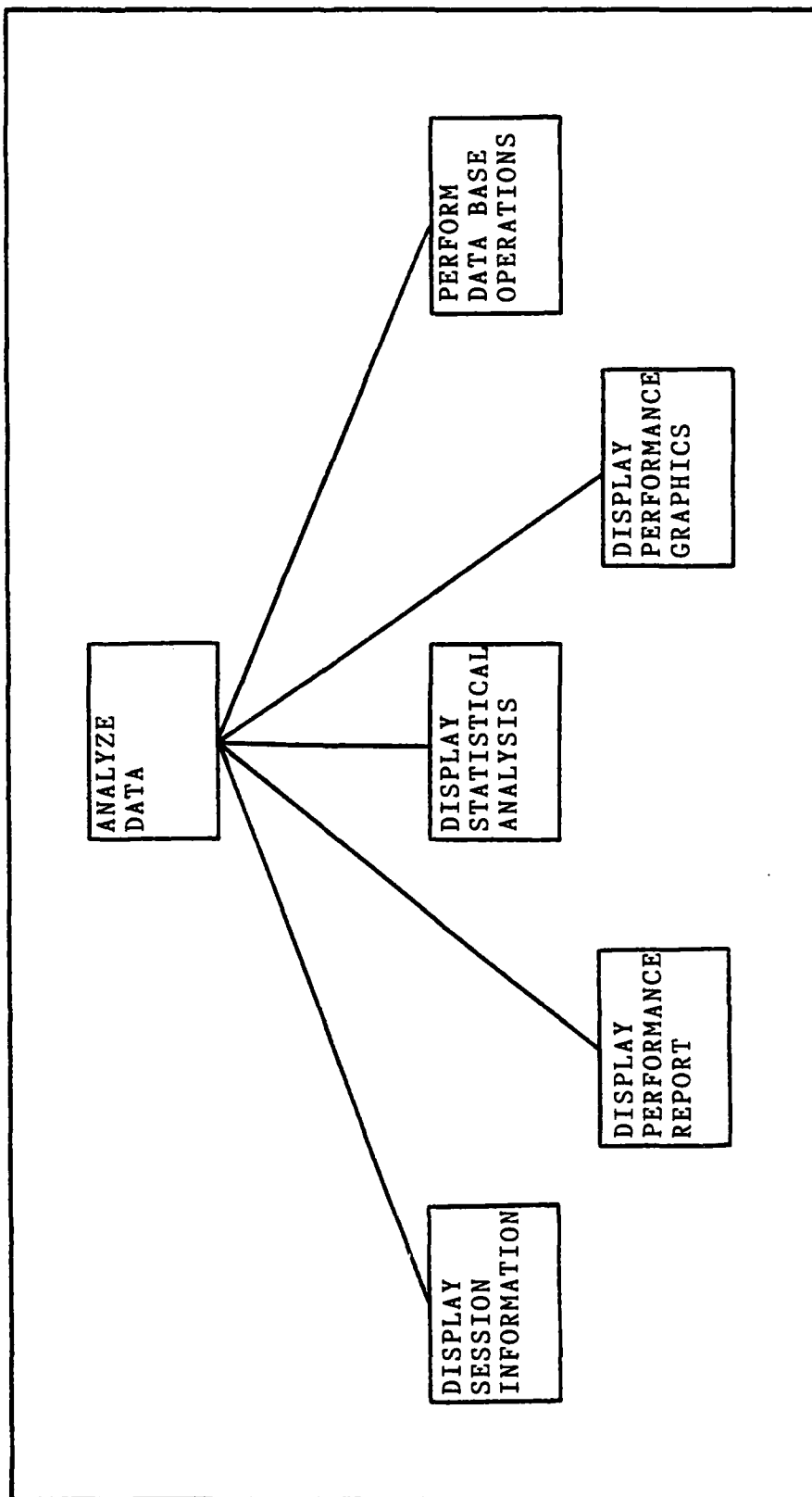


Figure IV-3 ~ Data Analysis Block Diagram.

performance data can be either the measurement file from the measurement session or the instrument file from the instrument session.

The SDSS menu options for data analysis are: Display Session Information, Display Performance Report, Display Statistical Analysis, Display Performance Graphics, and Perform Data Base Operations. Of these, the Display Session Information and the Display Performance Report were implemented in this thesis. The performance report allows selection of performance data by performance measure and performance index. The performance data is displayed for the user a screen at a time by performance parameter. The Exit Program selection of DBMON provides the user with instructions for initiating the measurement session and terminates the User Interface. This section of the User Interface was implemented in an earlier thesis (1).

Test Summary. The User Interface was tested against the test plan presented in chapter III. The testing was completed successfully and no design changes were required. The Test Plan is contained in the system design documentation (1: Appendix D).

Measurement Session. The Measurement Session controls the collection of measurement performance data, generates the measurement file, prints the measurement report, and keeps the status of the measurement session.

Data Structures. The Measurement Session process uses the measurement session file, parameter file, tool files, measurement file, and instrument file. The parm file is used by the Mergdata program to find performance parameters in the monitor file. It contains the parameters, performance measure, and performance index which simplifies formatting of data from the monitor file. The measurement and instrument files contain the performance measure, performance index, performance parameter, parameter source, and parameter value. These files are sorted into the format of the performance reports.

Program Implementation. Figure IV-4 shows the block diagram of the Measurement Session. The Setrun program sets the status of the measurement session to indicate the session is currently running. The Measurement Tools commands initiate the performance tools which collect performance data into the tool files. The Mergdata program merges the performance data from the tool files, formats performance data into the measurement file, and sets the status of the measurement session as being completed. The Sort utility sorts the measurement file by performance

measure, performance index, and performance parameter. The measurement file is used by the User Interface to display the measurement report and/or the Prtreport program to print the measurement report on the system printer. The Prtreport program prints a banner page, prints the effectiveness section, and prints the efficiency section of the measurement report.

The Measurement Tool block is shown in Figure IV-5. The Measurement Tools initiates the monitor, account, and SYE system performance tools. The performance tool files generated by each utility is also shown in Figure IV-5.

The Measurement Session is a collection of Pascal programs and system performance tools executed by the command file generated in the User Interface. The command file is implemented using a VAX Command file (11). A sample measurement session command file is shown in Figure IV-6.

Test Summary. The Measurement Session was tested against the test plan presented in chapter III. The testing was completed successfully and no design changes were required. The Test Plan is contained in the system design documentation (1: Appendix D).

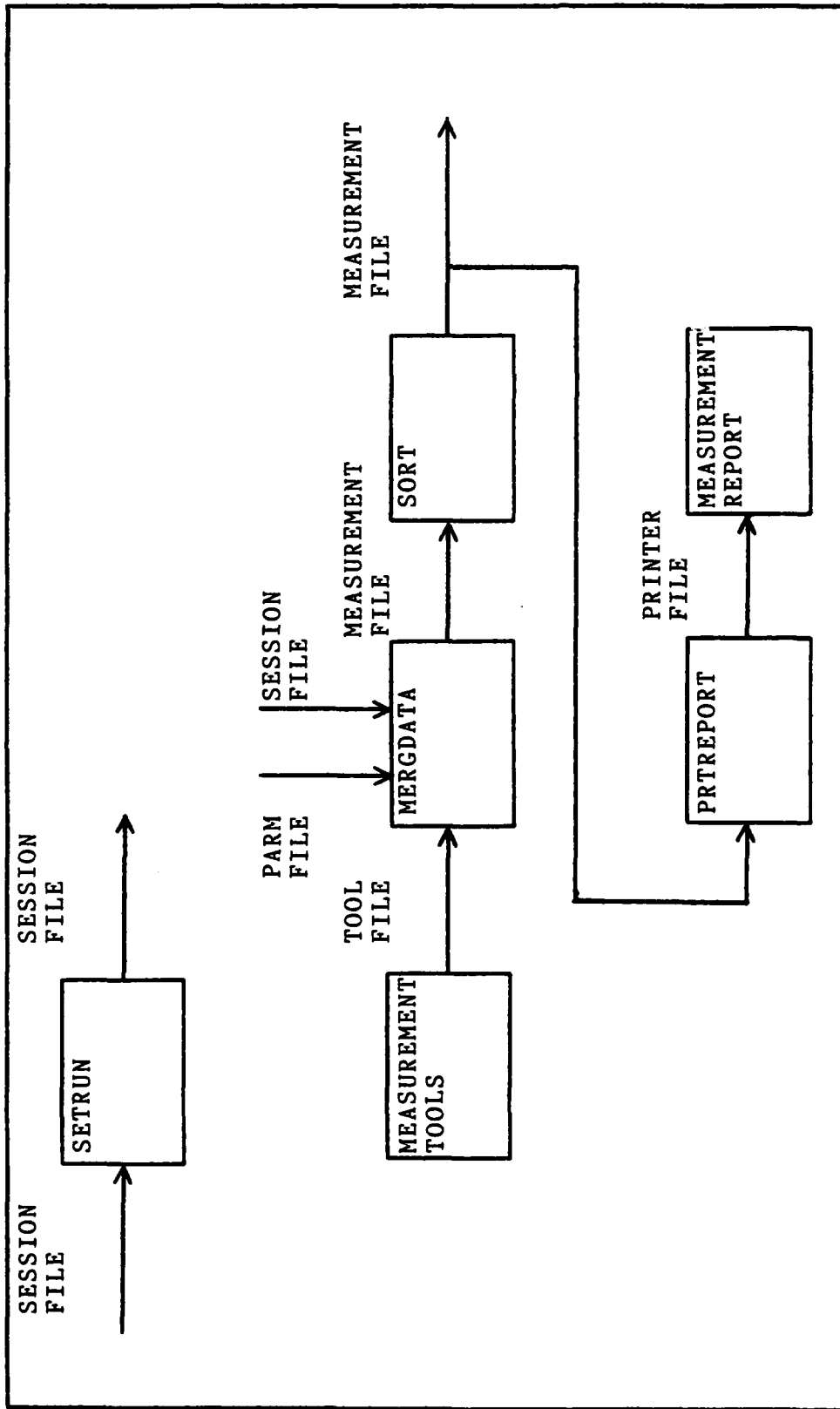


Figure IV-4 - Measurement Session Block Diagram.



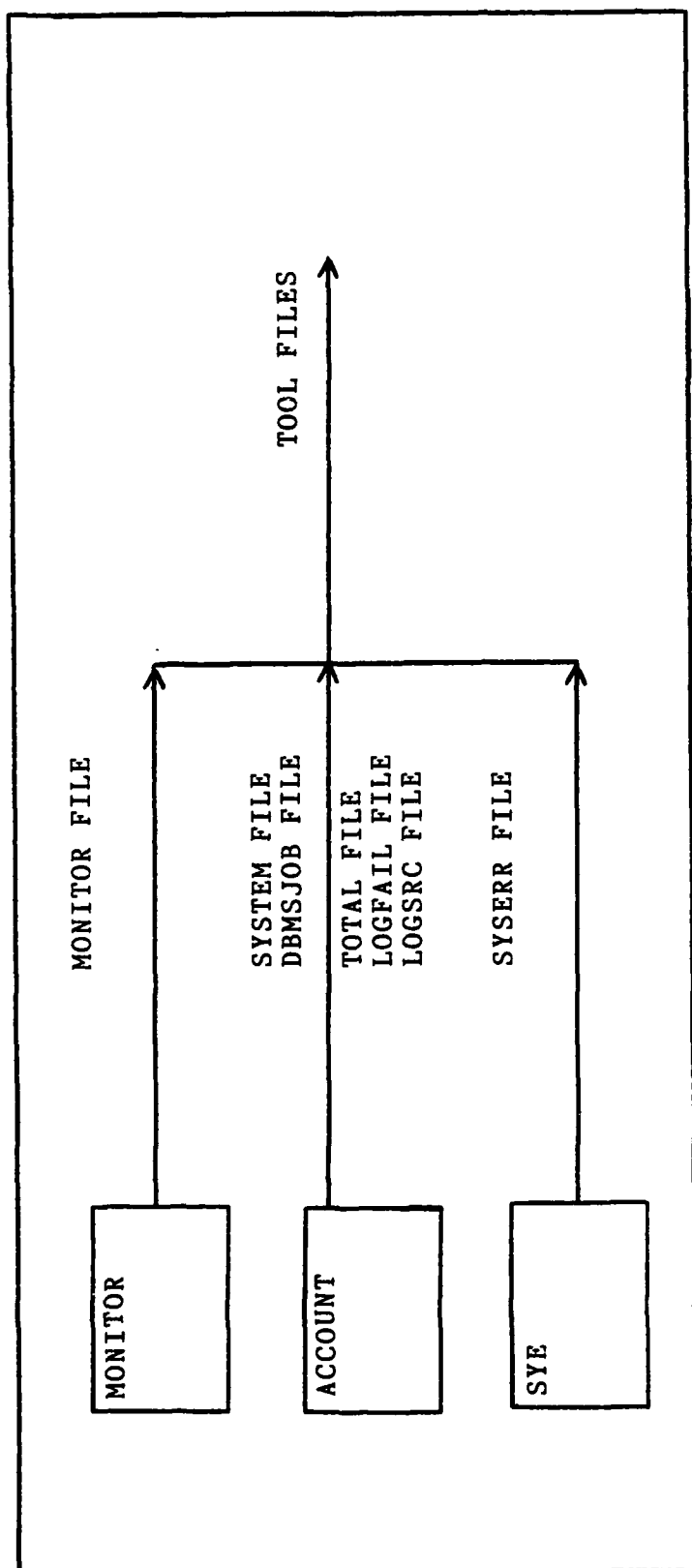


Figure IV-5 - Measurement Tools Block Diagram.

```

$!
$!***** INITIALIZE DATA FILES *****
$!
$SET DEF DUA0:[SYSO.SYSERR]
$RENAME ERRLOG.SYS ERRLOG.OLD
$SET DEF DUA1:[DBMON]
$SET UIC [203,003]
$RUN SETRUN
$!
$!***** MEASUREMENT CONTROL COMMANDS TO
$!***** INITIATE THE VAX MONITOR UTILITY
$!
$MONITOR IO/ALL,FCP/ALL,MODES/CPU/PERCENT/ALL,STATES/ALL -
/BEGINNING=18-OCT-1984:12:58:46 -
/ENDING=18-OCT-1984:24:00:00 -
/INTERVAL=60 -
/SUMMARY=DUA1:[DBMON]MONITOR.DAT
$!
$!***** DATA PRESENTATION COMMANDS TO
$!***** INITIATE DATA PRESENTATION SOFTWARE
$!
$SET DEF DUA1:[DBMON]
$RUN MERGDATA
$SORT/KEY=(POSITION:1,SIZE:30) PERFORM.DAT SORTOUT.DAT
$RUN PRTREPORT

```

Figure IV-6 Measurement Session Command File.

Instrument Session. The Instrument Session controls the collection of instrument data, generates the instrument file, and prints the instrument report.

Data Structures. The Instrument Session uses three sequential files. The Instrutil utilities write raw performance data to the Instr file. The Analdata program then formats the raw data into the instrument file and the instrument report.

Program Implementation. The block diagram for the Instrument Session is shown in Figure IV-7. Instrutil is a collection of MACRO-11 modules that are embedded into a TOTAL application program to collect performance data. These modules generate the Instr file. Instrutil was completed in an earlier thesis (1). The Analdata program formats the raw performance data into the report file and the instrument file. The Report file contains the instrument report and is printed on the system printer. The Instrument file is sorted by performance measure, performance index, and performance parameter by the VAX system sort utility. The Instrument file can then be displayed to the user by the User Interface. The Instrument Report section of the Instrument Session was also completed in an earlier thesis (1).

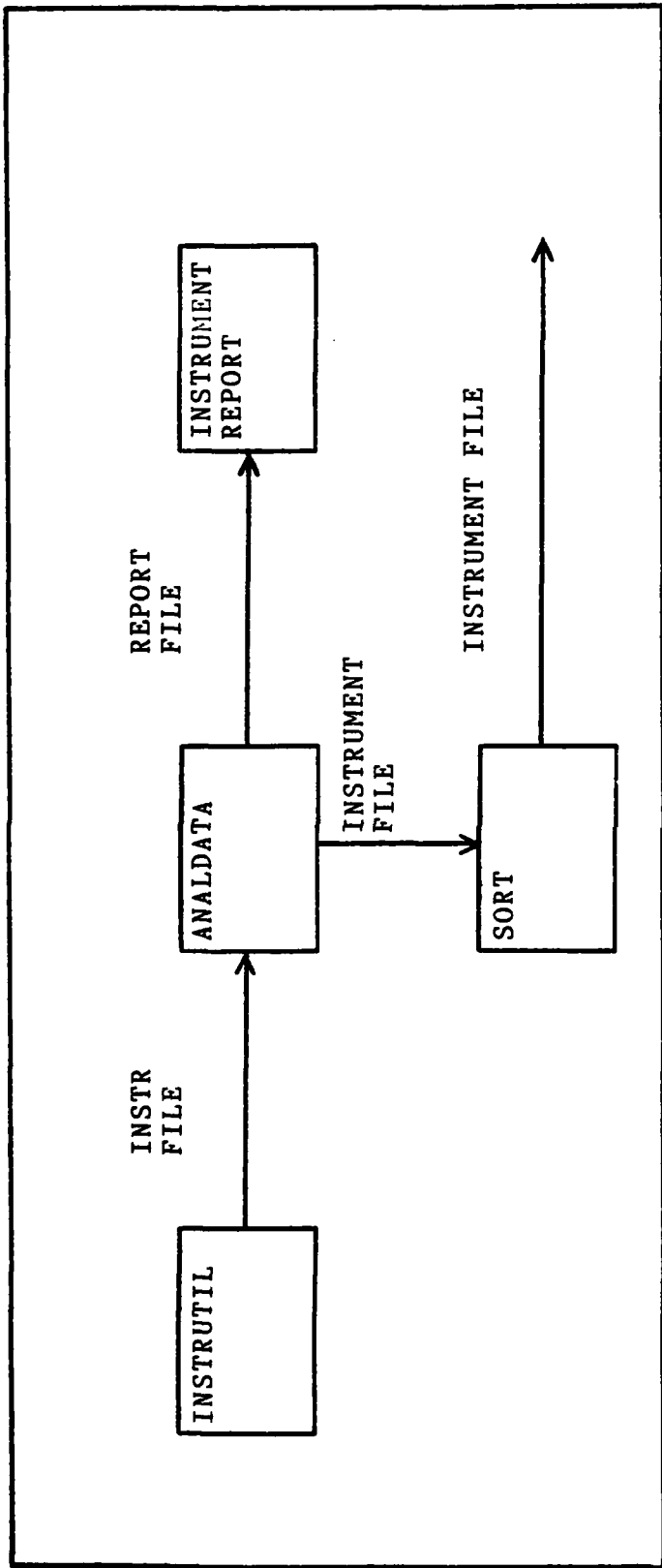


Figure IV-7 - Instrument Session Block Diagram.

Test Summary. The Instrument Session was tested against the test plan presented in chapter III. The testing was completed successfully and no design changes were required. The Test Plan is contained in the system design documentation (1: Appendix D).

#### DBMON Operation

The installation and operation procedures for the DBMS performance monitor are contained in the DBMON User Manual presented in Appendix F. The user manual contains a description of the DBMON user interface and the Instrument Utility, installation and modification procedures, and operational procedures.

## Summary

This chapter presented the high level view implementation and testing of the DBMS performance monitor on the VAX 11/780 using the VMS operating system. The chapter contained the VAX 11/780 configuration, the implementation plan, test procedures, performance measurement tools, measurable performance parameters, program language selection, software implementation, and DBMON operation. The software implementation section described the following DBMON activities:

1. User Interface
2. Measurement Session
3. Instrument Session

## V. Results, Conclusions, and Recommendations

### Introduction

This chapter presents the results from the development of the DBMS performance monitor, sample outputs from the testing of DBMON, conclusions, and recommendations.

### Results

The development of the DBMS performance monitor followed the earlier requirements, analysis, and general design approach (1). The following is a list of the development effort completed in this thesis investigation:

1. Design and implement the Instrument Report.
2. Design and implement the Measurement Report.
3. Design and implement the delete session menu of the User Interface.
4. Design and implement the show status menu of the User Interface.
5. Design and implement the parameter set options of the User Interface.
6. Design and implement the presentation options of the User Interface.
7. Requirements definition and design of the SDSS portion of the User Interface.

The analysis of the requirements and system design was treated as a reader kit. The reader kit was complete, accurate, and complete. Minor errors were found in syntax and consistency. The system design structure charts did not initially contain a data dictionary. The data dictionary would have been beneficial and was added to the current design.

The implementation of DBMON was completed with few problems. General routines such as DISPLAYMENU and USERPROMPT were used to be consistent with the original user interface standards (1). The only major problem encountered while implementing DBMON was the new versions VAX/VMS operating system, the Pascal compiler, and the Link utility. This required source code changes to all existing DBMON programs and the DBMON programs being developed.

#### Sample DBMS Performance Monitor Output

The output of the DBMS performance monitor is in the form of performance reports. These reports can be displayed to the user on a terminal and/or printed on the system printer. The Instrument Report is produced by the instrument session described in chapter IV. A sample page of the Instrument Report is shown in Figure V-1. The Measurement Report is produced by the measurement session also described in chapter IV. A sample page from this report is shown in Figure V-2.



# DNL STATEMENT SUMMARY

## RETRIEVAL COMMANDS

COMMAND NAME	TYPE INFORMATION	EXECUTION COUNT	RESPONSE TIME(SECS)	CPU TIME(MSEC)	BUFFERED I/O	DIRECT I/O	PAGE FAULTS	WORKING SET
RDWKT	TOTAL AVERAGE	511	15.148 0.030	5880 11.5	1022 2.0	306 0.6	18 0.0	100 100.0
RDWTH	TOTAL AVERAGE	37	2.010 0.054	520 14.1	74 2.0	37 1.0	2 0.1	100 100.0
RDWV	TOTAL AVERAGE	1172	22.920 0.020	11510 9.8	2344 2.0	110 0.1	8 0.0	100 100.0
-SUM-	TOTAL AVERAGE	1720	40.078 0.023	17910 10.4	3440 2.0	453 0.3	28 0.0	100 100.0

## STORAGE COMMANDS

NO STORAGE COMMANDS EXECUTED

## CONTROL COMMANDS

COMMAND NAME	TYPE INFORMATION	EXECUTION COUNT	RESPONSE TIME(SECS)	CPU TIME(MSEC)	BUFFERED I/O	DIRECT I/O	PAGE FAULTS	WORKING SET
SINON	TOTAL AVERAGE	2	3.040 1.530	1540 770.0	33 16.5	28 14.0	2116 1058.0	100 100.0
SINOF	TOTAL AVERAGE	2	3.330 1.665	940 470.0	18 9.0	28 14.0	1361 680.5	100 100.0
-SUM-	TOTAL AVERAGE	4	6.370 1.597	2480 620.0	51 12.8	56 14.0	3477 869.3	100 100.0

## SPECIAL PURPOSE COMMANDS

NO SPECIAL PURPOSE COMMANDS EXECUTED

## SUMMARY OF ALL COMMANDS

COMMAND NAME	TYPE INFORMATION	EXECUTION COUNT	RESPONSE TIME(SECS)	CPU TIME(MSEC)	BUFFERED I/O	DIRECT I/O	PAGE FAULTS	WORKING SET
-SUM-	TOTAL AVERAGE	1724	46.488 0.027	20390 11.8	3491 2.0	509 0.3	3505 2.0	100 100.0

Figure V-1 Instrument Report

```

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
X PERFORMANCE PARAMETER REPORT START TIME : 08-SEP-1984 13:24:56 X
X STOP TIME : 08-SEP-1984 24:00:00 X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

```

```

+*****+
+ EFFECTIVENESS PARAMETERS +
+*****+

```

# PRODUCTIVITY DATA

## SYSTEM THROUGHPUT

TYPE	USER	JOB NAME	RECORDS	ELAPSED TIME
PRINT	BAILOR	MERGDATA	10	00:01:04.08
PRINT	ENET	THESES	20	00:02:10.59
PRINT	PANGMAN	CALCFRM	10	00:00:22.95
PRINT	SYSTEM	SYE	20	00:00:34.58
PROCESS	BAILOR		30	02:03:44.61
PROCESS	EEA46		20	00:20:52.94
PROCESS	ENET		20	02:49:56.27
PROCESS	PANGMAN		20	02:28:10.00

# INTEGRITY DATA

## DEVICE ERRORS

DEVICE	HARD	SOFT	ERRORS THIS SESSION
_DMA0:	1.		1.
_DMA1:			2.
_DMA1:		92.	130.
_DMA2:		33.	51.

## SYSTEM ERROR SUMMARY

DEVICE ERROR BIT SET	1.
SYSTEM START-UP	3.

# SECURITY DATA

## LOGIN FAILURES BY USER

USER	ACCESS ATTEMPTS
(LOGIN)	2

Figure V-2 Measurement Report

## Conclusions

The following form the conclusions from the study of the DBMS performance monitor.

1. The functional requirements and generalized design of the DBMS performance monitor were valid for the implementation of DBMON on the VAX 11/780.

2. The software development tools of Data Flow Diagrams, SADT Diagrams, Structure Charts, Data Dictionaries, and documented code were valuable in both the implementation of new software, and the modification and maintenance of existing software.

3. The DBMS performance monitor is a valuable performance analysis tool for both system analysis and DBMS analysis.

## Recommendations

The following recommendations are made for continued development of the DBMS performance monitor:

1. The Specific Decision Support System (SDSS) section of the User Interface should be implemented. This would allow the user of DBMON to perform graphic, statistical, and data base operations on the performance data.

2. The performance report section of the User Interface should be modified to allow the selection of the performance parameters based on the type of user, such as Data Base Administer, Software Engineer, DBMS Designer, etc.

3. The measurement and instrument sessions should be changed to allow multiple performance files to be active and selectable in the User Interface. Currently the performance file selected is the file with the highest VAX version number.

4. The User interface should be modified to allow selected screens of performance data to be printed directly to the system printer.

5. The DBMS performance monitor should be used to test and tune operational Data Base application programs.

6. The Instrument Utility should be expanded to collect data on other DBMSs besides TOTAL, such as INGRES.

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This investigation focuses on the problem of analyzing the performance data collected on a Data Base Management System (DBMS). The performance data parameters are categorized and presented to the user using a Data Support System (DSS).

The generalized design for a DBMS performance monitor was used to design a user-friendly interface to DBMS performance data. The user interface to the DBMS performance monitor uses menus to allow the user to select DBMS performance parameter values. The DBMS performance parameter values can also be printed in the form of a performance report.

The design was implemented on a VAX 11/780 computer system using the VMS operating system. The TOTAL DBMS was used to collect performance data. The performance values were collected using existing software monitors, job accounting, system error log, and a utility developed at AFIT to collect Data Manipulation Language (DML) response performance data.

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